(12) UK Patent Application (19) GB (11) 2 370 725 (13) A

(43) Date of A Publication 03.07.2002

(21) Application No 0111897.5

(22) Date of Filing 16.05.2001

(30) Priority Data
(31) 00083255 (32) 27.12.2000 (33) KR

(71) Applicant(s)
Electronics and Telecommunications Research Institute
(Incorporated in the Republic of Korea)
161 Kajong-dong, Yusong-gu, Taejon, Republic of Korea

(72) Inventor(s)
Il-Gyu Kim
Jae-Wook Jeong
Seung-Chan Bang

(74) Agent and/or Address for Service
Eric Potter Clarkson
Park View House, 58 The Ropewalk, NOTTINGHAM, NG1 5DD, United Kingdom

(51) INT CL[7]
H04Q 7/38

(52) UK CL (Edition T)
H4L LRPMW L201 L213

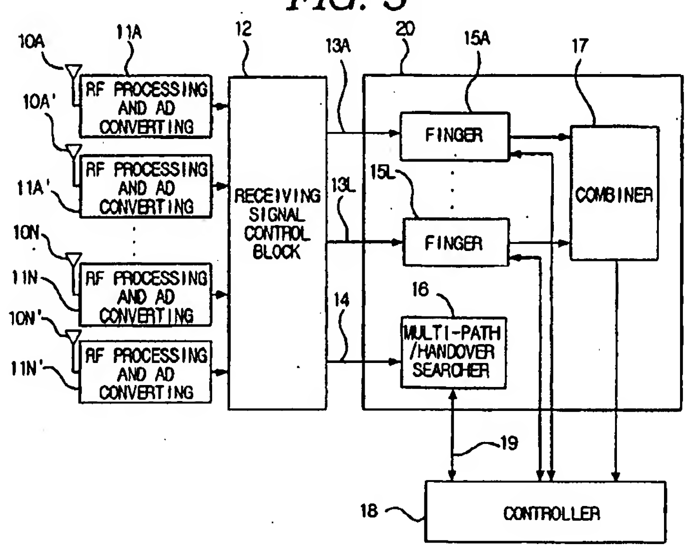
(56) Documents Cited
GB 2318952 A WO 00/25530 A2

(58) Field of Search
UK CL (Edition S) H4L LRPMA LRPMW LRRMW
INT CL[7] H04Q 7/38
Online: WPI, EPODOC, JAPIO

(54) Abstract Title
Optimal search method of DS-CDMA signal composed of time multiplexed known symbols and unknown symbols

(57) There is disclosed an optimal search method of DS-CDMA signals consisted of time-multiplexed pilot symbols and control symbols capable of maximizing the performance of a receiver when the signal is searched or SNR is measured and apparatus thereof. Further, the present invention proposes a method of maximizing the performance of a searcher using basically both energy of the pilot symbol and the control symbol wherein coherent integral lengths for two regions are differentiated when the receiver searches the signals, and different weights are given to the two regions when a coherent correlation value is finally non-coherently added, and a method of effectively estimating SNR.

FIG. 3



GB 2 370 725 A

FIG. 1

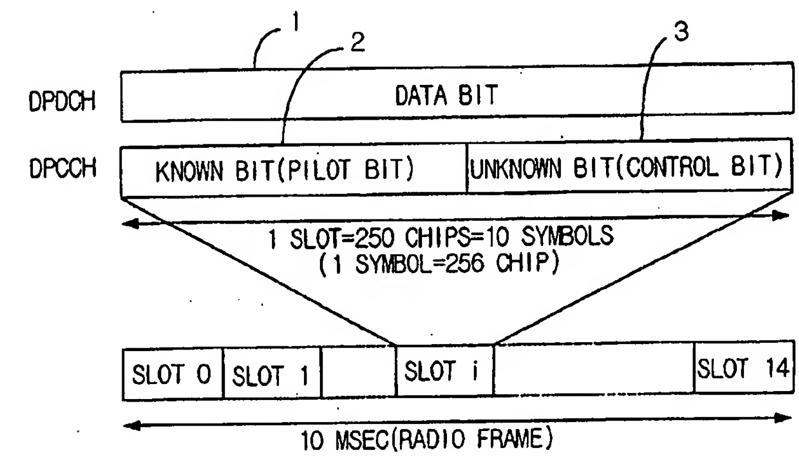

1
2
3
DPDCH
DATA BIT
DPCCH
KNOWN BIT(PILOT BIT)
UNKNOWN BIT(CONTROL BIT)
1 SLOT=250 CHIPS=10 SYMBOLS
(1 SYMBOL=256 CHIP)
SLOT 0
SLOT 1
SLOT i
SLOT 14
10 MSEC(RADIO FRAME)

FIG. 2

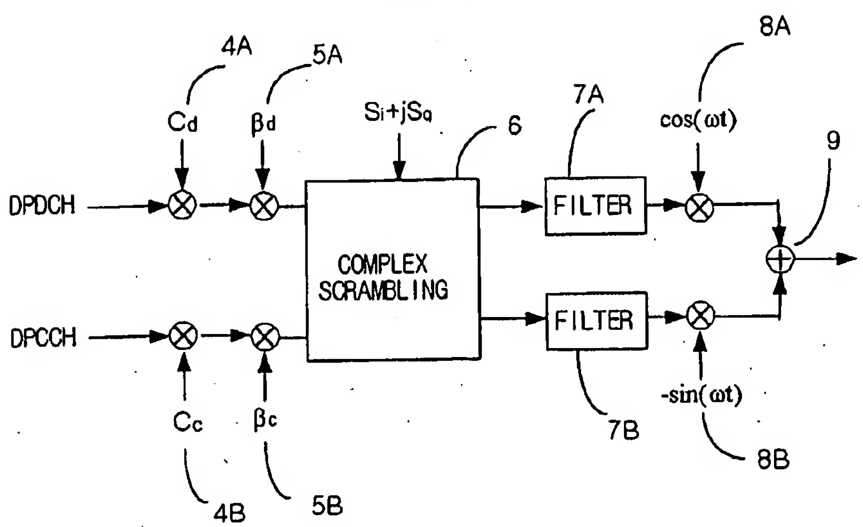

4A
5A
8A
7A
Cd
βd
Si+jSq
6
cos(ωt)
9
DPDCH
COMPLEX
SCRAMBLING
FILTER
FILTER
DPCCH
-sin(ωt)
Cc
βc
7B
8B
4B
5B

FIG. 3

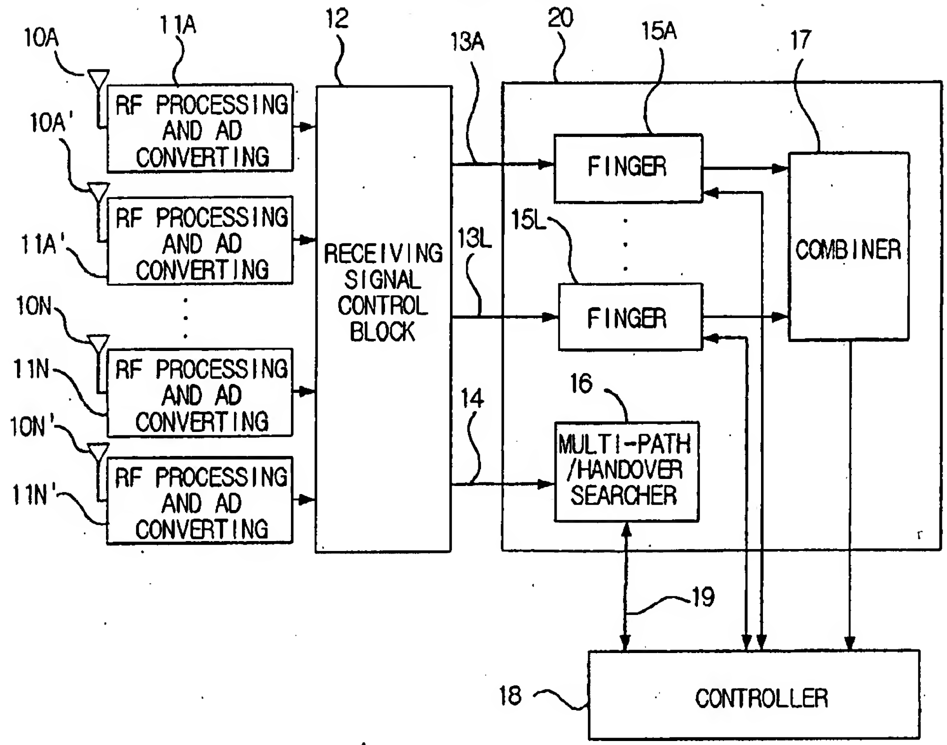
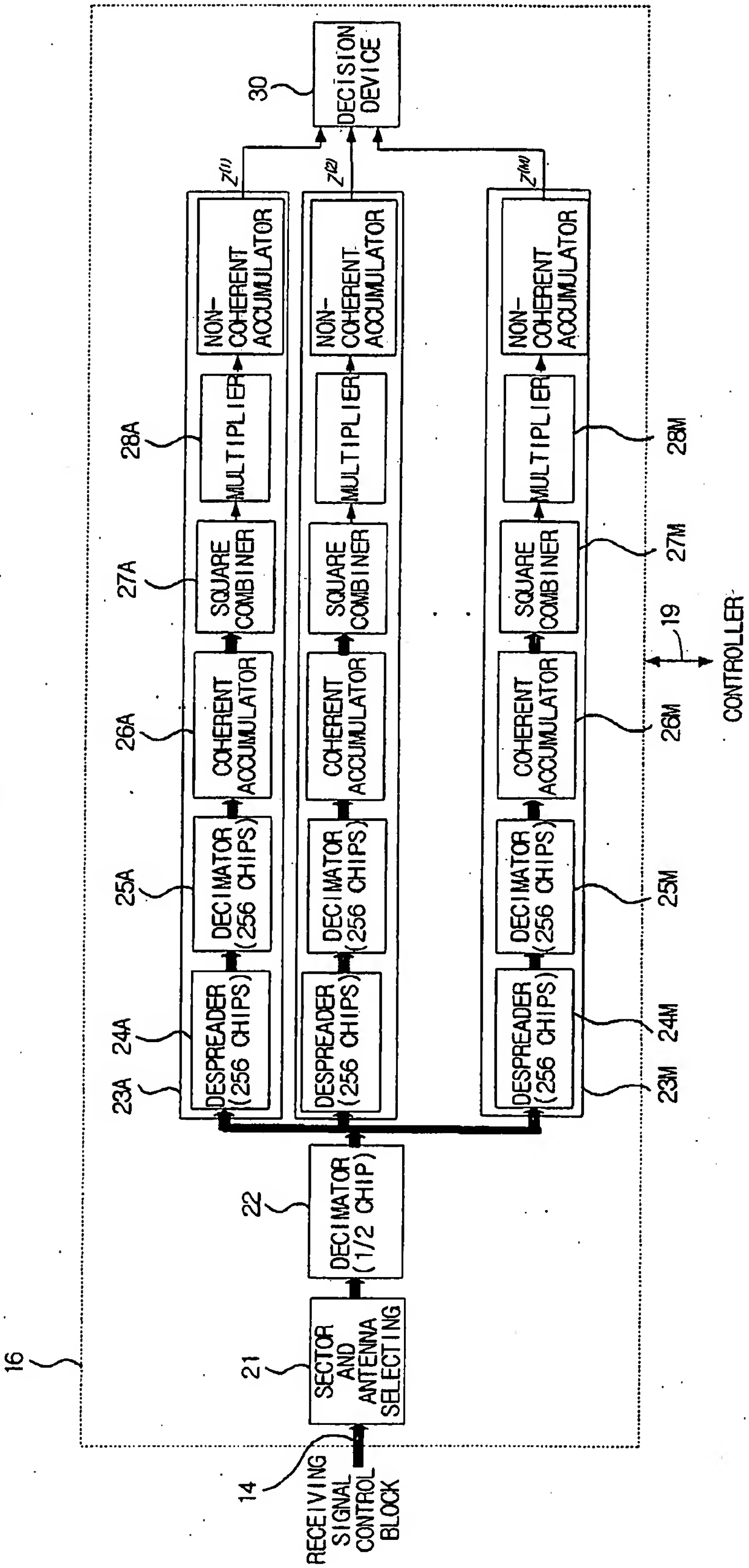

10A
11A
12
13A
20
15A
17
RF PROCESSING AND AD CONVERTING
10A'
RF PROCESSING AND AD CONVERTING
11A'
FINGER
15L
13L
RECEIVING SIGNAL CONTROL BLOCK
COMBINER
10N
FINGER
11N
RF PROCESSING AND AD CONVERTING
16
14
10N'
MULTI-PATH /HANDOVER SEARCHER
11N'
RF PROCESSING AND AD CONVERTING
19
18
CONTROLLER

FIG. 4



RECEIVING SIGNAL CONTROL BLOCK
14
16
21
SECTOR AND ANTENNA SELECTING
22
DECIMATOR (1/2 CHIP)
23A
24A
DESPREADER (256 CHIPS)
25A
DECIMATOR (256 CHIPS)
26A
COHERENT ACCUMULATOR
27A
SQUARE COMBINER
28A
MULTIPLIER
NON-COHERENT ACCUMULATOR
23M
24M
25M
26M
27M
28M
19
CONTROLLER
30
DECISION DEVICE

FIG. 5

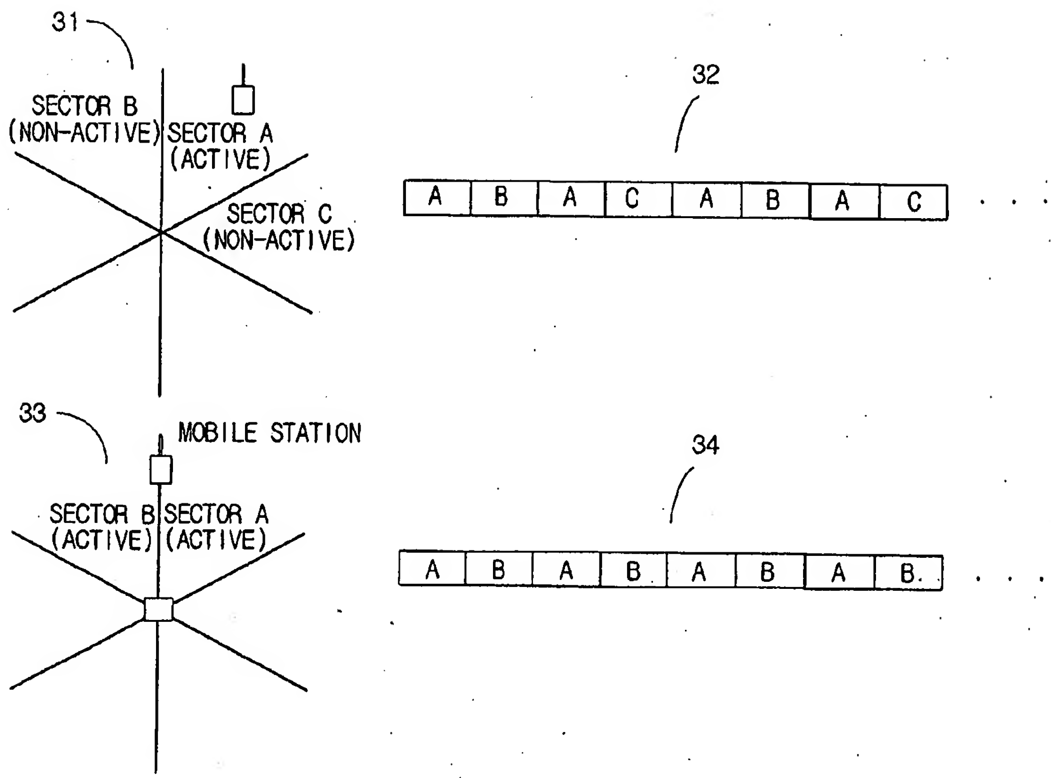
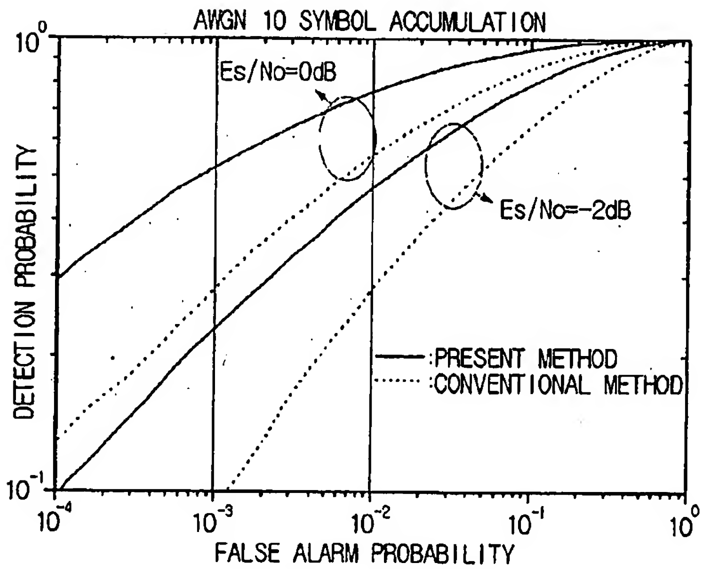

31
SECTOR B
(NON-ACTIVE)
SECTOR A
(ACTIVE)
SECTOR C
(NON-ACTIVE)
32
A B A C A B A C . . .
33
MOBILE STATION
SECTOR B
(ACTIVE)
SECTOR A
(ACTIVE)
34
A B A B A B A B . . .

FIG. 6


AWGN 10 SYMBOL ACCUMULATION
10^0
10^{-1}
DETECTION PROBABILITY
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
FALSE ALARM PROBABILITY
Es/No=0dB
Es/No=-2dB
:PRESENT METHOD
:CONVENTIONAL METHOD

2370725

OPTIMAL SEARCH METHOD OF DS-CDMA SIGNAL COMPOSED OF TIME MULTIPLEXED PILOT SYMBOLS AND CONTROL SYMBOLS

TECHNICAL FIELD

The invention relates to an optimal search method of DS-CDMA signals consisted of time-multiplexed pilot symbols and control symbols capable of maximizing the performance of a receiver when the signal is searched or SNR is measured using direct sequence spread-spectrum signals consisting of time-multiplexed pilot symbol region and control symbol regions, and apparatus thereof.

Also, the present invention proposes a method of maximizing the performance of the searcher using basically both the energy of the pilot symbol and the control symbol wherein coherent integral lengths for two regions are differentiated when a receiver searches the above signals, and different weights are given to the two regions when a coherent correlation value is finally non-coherently added, and a method of effectively estimating SNR.

BACKGROUND OF THE INVENTION

Next mobile communication system IMT-2000, being watched recently, can be classified into a satellite communication region and a terrestrial communication region. Fig. 1 illustrates an example of a wireless multi-connection technology in the terrestrial region of service systems according to IMT-2000, which shows a frame structure in an uplink DPCH (dedicated physical channel) of asynchronous W-CDMA scheme that has been now developed in 3GPP (3rd generation partnership project).

As shown in Fig. 1, the length of one (1) frame is 10 msec and is divided into 15 slots. One slot is 0.667 msec and corresponds to the 2560 chip length.

DPCH is consisted of DPDCH (dedicated physical data channel) and DPCCH (dedicated physical control channel), as shown in Fig. 1. DPDCH in Fig. 1 is used to

carry user's information bit 1 from an upper layer. The data transfer speed may be variable per frame. At this time, the minimal spreading factor is 4 and 256 at maximum.

On the other hand, DPCCH is consisted of a pilot region 2 for allowing coherent demodulation when a mobile station signal is demodulated in the base station, and a control region 3 for carrying information on the data transfer rate for data (1) of DPDCH, that is, control information such as a power control bit, etc.

In Fig. 1, the total number of DPCCH symbols transmitted during one slot is 10 symbols, which does not change. In other words, the spreading factor of DPCCH is always 256. Of ten symbols, the number of symbols in the pilot region may range from at least 3 to up to 8 depending on the slot format defined by W-CDMA rule. The slot format is determined when an initial call is established between the base station and the mobile station; The slot format can be changed during communication such as when the mode is changed from a normal mode to a compressed mode or vice versa, etc.

Table 1 below is a slot format of an uplink DPCCH that is defined in W-CDMA rule. In Table 1, slot formats to which A and B are attached are used for a compressed mode and remaining formats are used for a normal mode.

Table 1

Slot format	Channel symbol transfer rate (Ksps)	Spreadin g factor (SF)	Number of symbol per frame	Number of symbol per slot	Number of pilot (known) symbols	Number of pilot (un-known) symbol	Number of slot per frame
0	15	256	150	10	6	4	15
0A	15	256	150	10	5	5	10-14
0B	15	256	150	10	4	6	8-9
1	15	256	150	10	8	2	8-15
2	15	256	150	10	5	5	15
2A	15	256	150	10	4	6	10-14
2B	15	256	150	10	3	7	8-9
3	15	256	150	10	7	3	8-15
4	15	256	150	10	6	4	8-15
5	15	256	150	10	5	5	15
5A	15	256	150	10	4	6	10-14
5B	15	256	150	10	3	7	8-9

In Fig. 1, the pilot symbol 2 of DPCCH is masked by a pilot pattern in order to confirm frame synchronization. As the W-CDMA rule defines the pilot pattern depending on the number of the pilot symbol per slot, the pilot symbol is a known symbol to a receiver. On the other hand, as the control symbol 2 is randomly varied per slot or per frame, it is an unknown symbol until it is demodulated from a receiver's position.

DPDCH and DPCCH are firstly spread by an orthogonal code that the chip transfer speed is 3.84 Mcps, as shown in Fig. 2.

In Fig. 2, Cd (4A) and Cc (4B) each are orthogonal codes for separating DPDCH and DPCCH. After being spread into orthogonal codes, they are multiplied by a gain by βd

and βc, as in the block 5. Then, as in the block 6, they are complex-scrambled by a complex pseudo noise code of 3.84 Mcps.

The complex pseudo noise code is used to separate a plurality of mobile stations. A real number part and an imaginary number part of a demodulated scrambled signal each passes through a pulse shaping filter, as in the blocks 7A and 7B, and is then modulated 8. Then, they are amplified and then transmitted via an antenna.

After a call is established, the base station must continuously search multi-path components of a signal received from the mobile station using the DPCCH in Fig. 1, in order to allocate fingers. As the path of the received signal on a wireless channel continuously changes depending on the mobile station and surrounding environments, the receiver must continuously search multi-paths to allocate fingers in order for the call not to be disconnected.

In addition to the above-mentioned multi-path search, the base station must use DPCCH even when making a handover search for the mobile station that tries to make a handover from neighboring base station to the base station.

As in the example mentioned above, the structure of a receiver, which has been known to search receiving signals or measure the intensity of the signals using a direct sequence spread spectrum signal (DPCCH in the above example) in which the pilot symbol and the control symbol are time-multiplexed, employs both the energy of the pilot symbol region and the control symbol region. However, this structure makes same the coherent integral length of two regions and simply non-coherently adds the coherently integrated value without discriminating the pilot symbol region and the control symbol region. As this conventional receiver structure is not an optimal receiver, there is a problem that the performance of the receiver is significantly degraded at low signal to noise ratio.

SUMMARY OF THE INVENTION

The present invention is contrived to solve the above-mentioned problems and an object of the present invention is to provide a method and an apparatus maximizing the performance of a receiver when searching a signal or measuring SNR using a direct sequence spread spectrum signal composed of time-multiplexed pilot symbol region and control symbol region.

In order to accomplish the above object, an apparatus for optimally searching DS-CDMA signals consisted of time-multiplexed pilot symbols and control symbols according to the present invention is characterized in that it comprises a searcher including at least correlators having the same structures, the correlators maintaining the M number below the size of a search window to be searched; a sector and antenna selector for selecting a receiving signal of sectors and antennas that is to be searched by the searcher; a decimator for decimating the receiving signal of the selected sector and antenna -and for transferring data to the searcher so that a partial search window of a M/2 chip can be searched at a time if the size of a search step of 1/2 chip; and a decision device for performing one of the function of performing a multi-path search using both the energy of the pilot symbol and the control symbol, wherein coherent integral lengths for two regions are differentiated and wherein the two regions are given with different weights when a coherent correlating value is finally non-coherently added to produce accumulated values or the function of performing a handover search, and the function of detecting the intensity of a signal.

Further, the searcher includes a despreader for performing a complex dispreading operation by the length of symbols (256 chip) using code phase for M number of hypothesis; a decimator for decimating the despreading signals in the despreader by 256 chip unit and for selecting a transfer path whether the region of the decimated signal is the pilot symbol region or the control symbol region; a coherent accumulator for receiving signals that are determined to be the pilot symbol region in the decimator and for performing symbol by symbol coherent accumulation operation; a square combiner for receiving outputs of the coherent accumulator or signal that are determined to be the

control signal region in the decimator and for square-summing the real part and the imaginary part; a multiplier for receiving an output of the square combiner to perform a multiplication operation by which the output is bypassed if a current value belongs to the control symbol region and a weight value is given to the output if a current symbol belongs to the pilot symbol region; and a non-coherent accumulator for accumulating values received from the multiplier or the square combiner depending on various slot lengths controlled by a controller and for transferring the accumulated values to the decision device.

BRIEF DESCRIPTION OF THE DRAWINGS

The aforementioned aspects and other features of the present invention will be explained in the following description, taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a frame structure of an uplink DPCH of an asynchronous W-CDMA scheme;

Fig. 2 is a schematic diagram of an asynchronous W-CDMA mobile station transmitter;

Fig. 3 is a base station receiver structure according to the present invention;

Fig. 4 is a structure of a multi-path/handover searcher according to the present invention;

Fig. 5 is a search method by a multi-path searcher in a base station including multi-sectors according to the present invention; and

Fig. 6 is a graph illustrating a false alarm versus a detection probability comparing the present invention with prior art methods.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described in detail by way of a preferred embodiment with reference to accompanying drawings.

Fig. 3 illustrates one embodiment of a base station receiver structure which includes a multi-path searcher or a handover searcher using a method according to the present invention, manages a plurality of sectors and has two receiving antennas per sector.

In Fig. 3, a signal received via antennas 10A, 10A', 10N and 10N' in a base station is down-converted in a RF processing and AD converting blocks 11A, 11A', 11N and 11N', match-filtered in a pulse matching filter and is then A/D converted. The A/D converted signal has 4 or 8 sample values per chip.

Thereafter, a receiving signal control block 12 functions to distribute signals received from N number of sectors into a demodulating block 20 indicated by a reference numeral 20 within the base station. Though only one demodulating block 20 is shown in the receiving terminal of the base station, there may be practically a lot of demodulating blocks.

The demodulating block 20 includes a plurality of fingers 15A and 15L, a combiner 17 and a multi-path/handover searcher 16. Each of the three components is controlled by a controller 18.

The functions of the multi-path/handover searcher 16 are two: one is to continuously search multi-paths by establishing a given search window for a signal received from one or two sectors and another is to search a signal received from the mobile station which tries to make soft or hard handover from a neighboring base station to the current base station.

Fig. 4 illustrates one embodiment of a searcher according to the present invention.

The searcher according to the embodiment of Fig. 4 consists of M number of active correlators 23A to 23M. Each of the M number of correlators has the same structure. At this time, the parameter M may be the same as or greater than 1 and may be same as or below the search window size for which the searcher tries to search.

The M number of active correlators 23A and 23M may be implemented in the form of a code matching filter for which the size of a tap is M, which is covered by the present invention. The searcher in Fig. 4 is a searcher capable of searching a partial search window of M/2 chip at a time assuming that the size of the search step is a 1/2 chip.

Also, a sector and antenna selector 21, which is controlled by the controller, selects a sector that will be searched by the searcher and the signal received by the antenna. In Fig. 4, an arrow indicated by a bold line indicates that a complex value is passed and an arrow indicated by a solid line indicates that a real number part is passed.

Each of M number of despreaders 22 performs a complex despreading operation by symbols (256 chip) length, using code phases for M number of hypotheses. Each of I channel component and Q channel component of the compressed signal is decimated for every 256 chip in the decimator 25.

If the region of current despreading signal is the pilot symbol region, the output of the decimator 25 is inputted to the coherent accumulator 26. On the other hand, if the region of current despreading signal is the control symbol region, the output of the decimator 25 bypasses the coherent accumulator 26.

The reason the length of the coherent integration in the region of the control symbol could be not larger than the 256 chips is that it does not know the value of the control symbol until the control symbol is demodulated on the receiver's side. As in the example of Fig. 1, in case that the pilot symbol of the received signal is masked by the pilot pattern, a pilot pattern remover is inserted within (or in front of) the coherent integrator. (The pilot pattern remover is not shown in Fig. 4)

A square combiner 27 functions to square the complex output of the coherent accumulator 26 or the complex output of the decimator 25 and to then combine the squared real and imaginary values. Then, the output of the square combiner 27 is

inputted to the multiplier 28. If the current square combiner output corresponds to the control symbol region (the control symbol region, 3), it bypasses the multiplier 28 and enters the non-coherent accumulator. On the other hand, if the current square combiner output corresponds to the pilot symbol region (the pilot symbol region, 2), it enters the multiplier 28.

The multiplier 28 stores weight values corresponding to each of the slot formats defined in Table 1. The multiplier 28 also functions to multiply the weight value corresponding to the slot format of the transmit signal to the output of the square combiner. This will be explained in detail below.

The non-coherent accumulator 29 accumulates values received from the multiplier 28 or the square combiner 27 over several slot lengths. At this time, the accumulated slot length is controlled by the controller. Thus accumulated value is inputted to the decision device 30. The decision device 30 may be a block for performing a multi-path search, a block for performing a handover search or a block for detecting the intensity of signal.

The structure of the receiver described above will be below explained in detail by reference to the example in Table 1.

First, considering the slot format 0B in Table 1. In this case, the number of the pilot symbol per slot is 4 symbols and the number of the control symbol is 6 symbols.

In this case, the maximum coherent integration length for the pilot symbol region (pilot region) may be 4 symbols periods. If the integration length of the non-coherent accumulator 29 is 10 symbols(=1 slot period), the final decision variable for the m-th correlator ($1 \leq m \leq M$) can be expressed as the following Equation 1.

[Equation 1]

$$Z^{(m)} = \left(\left(\sum_{k=1}^{4} Z_I^{(m)}(k)\right)^2 + \left(\sum_{k=1}^{4} Z_Q^{(m)}(k)\right)^2\right) \times \lambda^{(0B)} + \sum_{k=5}^{10}\left\{\left(Z_I^{(m)}(k)\right)^2 + \left(Z_Q^{(m)}(k)\right)^2\right\}$$

The front part in Equation 1 indicates a value in which the real part and the imaginary part each are coherently accumulated during 4 symbols period for the pilot symbol (or know symbol) region and are then combined by square. On the other hand, the latter part in Equation 1 indicates a value in which the real part and the imaginary part each are coherently accumulated during 1 symbol period (256 chips) for the control symbol (or unknown symbol) region, combined by square and then non-coherently added during 6 symbol periods.

Also, $\lambda^{(0B)}$ indicates a weight value for the slot format 0B. The receiver of the present invention stores the weight value.

If the integration period of the non-coherent accumulator 29 according to the present invention is more than 10 symbols (=1 slot), the procedure given by the above Equation 1 is repeatedly accumulated. Though a weight value is added to a portion corresponding to the pilot region in the explanation of Equation 1 and Fig. 4, a method of giving a weight value to the control region may be considered. This method is also covered by the present invention.

In an ideal channel environment, as the coherent integration period of the coherent accumulator 26 for the pilot region is greater, the performance of the receiver becomes better. In a wireless channel environment, however, if the Doppler frequency is great depending on the speed of the mobile station, when the coherent integration period of the coherent accumulator 26 for the pilot region is larger than the coherent period of the channel, there may be caused a problem that the performance of the receiver is degraded.

In this case, the present invention proposes a method by which the coherent integration period is divided into two or more than. For example, considering the slot format 1 in Table. In this case, the number of the pilot symbol per slot is 8. The final decision variable for this can be expressed as the following Equation 2.

[Equation 2]

$$Z^{(m)}=\left(\left(\sum_{k=1}^{4}Z_I^{(m)}(k)\right)^2+\left(\sum_{k=1}^{4}Z_Q^{(m)}(k)\right)^2\right)\times\lambda^{(1)}+\left(\left(\sum_{k=5}^{8}Z_I^{(m)}(k)\right)^2+\left(\sum_{k=5}^{8}Z_Q^{(m)}(k)\right)^2\right)\times\lambda^{(1)}$$
$$+\sum_{k=9}^{10}\left\{\left(Z_I^{(m)}(k)\right)^2+\left(Z_Q^{(m)}(k)\right)^2\right\}$$

In Equation 2, former two parts indicate integral values for the pilot region and the latter part corresponds to an integral value for the control symbol region. In the second example of the present invention, assuming that the coherent period of the channel is 4 symbols region, the pilot region of 8 symbols is divided into two regions, which is then multiplied by the same weight values. $\lambda^{(1)}$ is a weight value for the slot format 1 in Table 1 which is stored in the receiver of the present invention. If the integration period of the non-coherent accumulator 29 of the present invention is more than 10 symbols (=1 slot), the procedure given in Equation 2 is repeatedly performed.

If the pilot symbol region is an odd number and is greater than the coherent integral period of the channel, as in the slot format 3 of Table 1, the pilot region can be expressed as follows.

[Equation 3]

$$Z^{(m)}=\left(\left(\sum_{k=1}^{4}Z_I^{(m)}(k)\right)^2+\left(\sum_{k=1}^{4}Z_Q^{(m)}(k)\right)^2\right)\times\lambda_1^{(3)}+\left(\left(\sum_{k=5}^{7}Z_I^{(m)}(k)\right)^2+\left(\sum_{k=5}^{7}Z_Q^{(m)}(k)\right)^2\right)\times\lambda_2^{(3)}$$
$$+\sum_{k=8}^{10}\left\{\left(Z_I^{(m)}(k)\right)^2+\left(Z_Q^{(m)}(k)\right)^2\right\}$$

In Equation 3, former two parts indicate integral values for the pilot region and the latter part corresponds to an integral value of the control symbol region. In the third example of the present invention, assuming that the coherent period of the channel is 4 symbols region, the pilot region of 7 symbols is divided into two regions, which is then multiplied by different weight values. $\lambda_1^{(3)}$ and $\lambda_2^{(3)}$ are weight values for the slot format 3 in Table 1 which is stored in the receiver of the present invention.

As in Equation 3, the reason different weight values are multiplied is that the coherent integral lengths of the two regions are differentiated. If the integration period of the

non-coherent accumulator 29 is more than 10 symbols (=1 slot), the procedure given in Equation 3 is repeatedly performed.

To sum up the above examples 1, 2 and 3, it can be expressed into the following Table 2.

□Table 2□

Slot format #1	Number of pilot symbols	First coherent integral length (symbol)	Second coherent integral length (symbol)	Weighting factor
0	6	3	3	$\lambda^{(0)}$
0A	5	5	0	$\lambda^{(0A)}$
0B	4	4	0	$\lambda^{(0B)}$
1	8	4	4	$\lambda^{(1)}$
2	5	5	0	$\lambda^{(2)}$
2A	4	4	0	$\lambda^{(2A)}$

In the receiver of the present invention, as in Table 2, the integral length and the weight vector of each of the slot formats are stored. When a call is established, a value corresponding to the format is used.

In case that the multi-path searcher of the present invention is used in the base station receiver including more than two sectors, if the number of an active sector of the up link communicating with the mobile station is 1, the multi-path searcher searches neighboring non-active sectors as well as a current active sector in a time division multiplexing (TDM) scheme.

Fig. 5 illustrates an exemplary 6 sector base station. If the number of an active sector is one (31), the base station searcher of the present invention searches three non-active sectors including neighboring two non-active sectors as well as a current active sector

in a time division multiplexing (TDM) scheme (32). And if the number of an active sector is two (33), the base station searcher of the present invention searches 2 active sectors in a time division multiplexing (TDM) scheme (34).

The most significant advantage of the direct sequence CDMA system is that the performance of the receiver can be maximized due to the path diversity effect that is caused since various multi-path components are rake-combined. The multi-path, however, is not fixed but is continuously varied on the time axis depending on the speed of the mobile station.

The multi-path searcher continues to search multi-paths by establishing a certain search window under this time-varying channel situation and passes over information on each of the channels to the controller. Information on the multi-paths includes information on the signal intensity of each of the paths (or SNR) as well as delay information on each of the paths.

In the multi-path searcher of the present invention, a method of estimating SNR in a certain path uses outputs from the M number of non-coherent accumulators 29 in a parallel correlator, wherein the ratio between the accumulated output in a selected path and averaged accumulated output of remaining paths is used.

A decision device 30 in the multi-path searcher of the present invention sequentially selects L number of significant outputs from the M number of the non-coherent accumulator outputs in the order of their strengths.

The multi-path searcher estimates [Es/Io] value for each of the selected L number of paths and passes over the results to the controller.

At this time, Es means the energy per symbol of the received signal and Io means the density of the total noise power. Of the L number of paths, assuming that the [Es/Io]

value of the i-th path is set to $[Es/Io]l_i$, the $[Es/Io]l_i$ value can be expressed into the following Equation 4.

[Equation 4]

$$[Es/Io]_{l_i} = \frac{(\lambda_1 N_{c1} + \lambda_2 N_{c2} + 10 - N_{c1} - N_{c2})}{\lambda_1 (N_{c1})^2 + \lambda_2 (N_{c2})^2 + 10 - N_{c1} - N_{c2}} (\Gamma^{(l_i)} - 1)$$

In Equation 4, N_{c1} represents the first coherent integration length in the symbol unit shown in Table 2 and λ_1 represent the weight factor for the first coherent integration region. Also, N_{c2} represents the second coherent integration length of the symbol unit shown in Table 2 and λ_2 represent the weight factor for the second coherent integration region. In case that the second coherent integration length is 0, $[Es/Io]l_i$ of the l_i-th path can be expressed into the following Equation 5.

[EQUATION 5]

$$[Es/Io]_{l_i} = \frac{(\lambda N_c + 10 - N_c)}{\lambda (N_c)^2 + 10 - N_c} (\Gamma^{(l_i)} - 1)$$

In Equations 4 and 5, $\Gamma^{(l_i)}$ is the output from the non-coherent accumulator 19 for the path l_i divided by the average of outputs from the non-coherent accumulators 19 for the M-L number of paths except for the selected L number of paths, which can be expressed into the following Equation 6.

[EQUATION 6]

$$\Gamma^{(l_i)} = \frac{Z^{(l_i)}}{\frac{1}{M-L} \sum_{\substack{m=1 \\ m \neq l_1 \\ \vdots \\ m \neq l_L}}^{M} Z^{(m)}}$$

A method of measuring SNR of the multi-path searcher of the present invention is based on the Equations 6 and 4 or Equation 5.

As can be seen from Fig. 6, there is shown a graph illustrating a false alarm versus a detection probability when the conventional method and the present method are applied to the multi-path searcher. The drawing takes an example when five symbols of ten symbols are the pilot symbol and the remaining portions are the control symbol. In case of the present method, the coherent integration length of the pilot region was set to 5 symbols period and an optimal weight value factor was used in the simulation for performance analysis. From the drawing, it can be seen that the method of the present invention has a good performance in view of the detection probability of the signal compared to the conventional method.

As mentioned above, the present invention employs both the pilot region and control region when searching a direct sequence spread-spectrum signal in which a pilot symbol region and a control symbol region are consisted in a time division multiplexing (TDM) scheme or measuring the SNR of the signal, wherein two portions are given with different weight values when the correlating value for the two regions of the present invention is non-coherently added. Therefore, the present invention can maximize the performance of the receiver.

Also, according to the present invention, there is proposed a method of differently setting the weight values for the slot formats. Thus, it can maximize the performance of the receiver for each of the slot formats.

The present invention has been described with reference to a particular embodiment in connection with a particular application. Those having ordinary skill in the art and access to the teachings of the present invention will recognize additional modifications and applications within the scope thereof.

It is therefore intended by the appended claims to cover any and all such applications, modifications, and embodiments within the scope of the present invention.

CLAIMS

1. An apparatus for optimally searching DS-CDMA signals consisted of time-multiplexed known pilot symbols and unknown control symbols, comprising:

a searcher including at least correlators having the same structures, said correlators maintaining the M number below the size of a search window to be searched;

a sector and antenna selector for selecting a sector and antenna from sectors and antennas that is to be searched by said searcher;

a decimator for decimating the receiving signal from the selected sector and antenna and for transferring data to said searcher so that a partial search window of a M/2 chip can be searched at a time if the size of a search step of 1/2 chip; and

a decision device for performing one of the function of performing multipath search or the function of detecting the intensity of a signal, wherein both the energy of the pilot symbol and the control symbol are used, wherein coherent integration lengths for two regions are differentiated and wherein the two regions are given with different weights when the coherent correlating values are finally non-coherently combined to produce an accumulated decision value

2. The apparatus according to claim 1, wherein said searcher further includes:

a despreader for performing a complex dispreading operation by the length of symbols (256 chip) using code phase for M number of hypothesis;

a decimator for decimating the despreaded signals in said despreader by 256 chip unit and for selecting a transfer path whether the region of the decimated signal is the pilot symbol region or the control symbol region;

a coherent accumulator for receiving signals that are determined to be the pilot symbol region in said decimator and for performing a symbol by symbol coherent accumulation operation;

a square combiner for receiving outputs of said coherent accumulator or signal that are determined to be the control signal region in said decimator and for square- summing the real part and the imaginary part;

a multiplier for receiving an output of said square combiner to perform a multiplication operation by which the output is bypassed if a current value belongs to the control symbol region and.a weight value is given to the output if current symbol belongs to the pilot symbol region; and

a non-coherent accumulator for accumulating values received from said multiplier or said square combiner depending on various slot lengths controlled by a controller and for transferring the accumulated values to said decision device.

3. A method of optimally searching a signal in which a pilot symbol region and a control symbol region are consisted in a time multiplexing scheme and which is experienced by direct sequence spread-spectrum using pseudo noise code, comprising:

a first step of using both the energy of the pilot symbol region and the control symbol region of a received signal, wherein coherent integration periods for two regions are differentiated; and

when coherently correlating values for the pilot symbol region and the control symbol region of the received signal are finally non-coherently combined,

$$Z^{(m)} = \left(\left(\sum_{k=1}^{4} Z_I^{(m)}(k) \right)^2 + \left(\sum_{k=1}^{4} Z_Q^{(m)}(k) \right)^2 \right) \times \lambda^{(0B)} + \sum_{k=5}^{10} \left\{ \left(Z_I^{(m)}(k) \right)^2 + \left(Z_Q^{(m)}(k) \right)^2 \right\}$$

a second step of giving different weights values to said two parts, as in the above Equation.

4. The method according to claim 3, wherein said first step further includes:

a first step of dividing a coherent integral period of the pilot symbol region into more than two periods when the pilot symbol region of the received signal is larger than the coherent period of the channel;

when the coherent integral value for the pilot symbol region divided into more than two periods in said first sub-step is finally non-coherently added,

$$Z^{(m)} = \left(\left(\sum_{k=1}^{4} Z_I^{(m)}(k) \right)^2 + \left(\sum_{k=1}^{4} Z_Q^{(m)}(k) \right)^2 \right) \times \lambda_1^{(3)} + \left(\left(\sum_{k=5}^{7} Z_I^{(m)}(k) \right)^2 + \left(\sum_{k=5}^{7} Z_Q^{(m)}(k) \right)^2 \right) \times \lambda_2^{(3)}$$
$$+ \sum_{k=8}^{10} \left\{ \left(Z_I^{(m)}(k) \right)^2 + \left(Z_Q^{(m)}(k) \right)^2 \right\}$$

a second sub-step of giving a weight value of each of the portions wherein former two parts are integral values for the pilot symbol region and the latter part is an integral value for the control symbol region, as in the above Equation.

5. The method according to claim 3, wherein said second step further includes:

a first step of storing a weight value for each of previously set slot formats in the receiver, and

a second step of using corresponding coherent integral length and weight value when a slot format per frame is changed.

6. The method according to claim 3, wherein in case that the multi-path searcher is used in a base station receiver including more than two sectors, if the number of active sectors of uplink for the mobile station is 1, neighboring non-active sectors as well as a current active sector are searched in time division scheme.

7. The method according to claim 3, wherein in case that the multi-path searcher is used in a base station receiver including more than two sectors, if the number of active sectors of uplink for the said mobile station is 2, the two active sectors are searched in a time division multiplexing scheme.

8. The method according to claim 3, further including a third step of calculating a signal to noise ratio (SNR) for a path by the multi-path searcher using outputs from the M number of non-coherent accumulators wherein the ratio of the output of selected path and the average of the outputs of remaining paths are used.

9. The method according to claim 8, wherein said third step further includes:

a first step of sequentially selecting the L number of significant outputs from the M outputs of non-coherent combiners in the order of their strength;

for a path of the L number of paths selected through said first step,

$$\Gamma^{(l_i)} = \frac{Z^{(l_i)}}{\frac{1}{M-L}\sum_{\substack{m=1\\ m\neq l_1\\ \vdots\\ m\neq l_L}}^{M} Z^{(m)}}$$

a second step of obtaining the mean ratio of the outputs of the non-coherent accumulators for the M-L number of remaining paths; and

a third step of substituting the ratio obtained through said second step below Equation to produce the results,

$$[Es/Io]_{l_i} = \frac{(\lambda_1 N_{c1} + \lambda_2 N_{c2} + 10 - N_{c1} - N_{c2})}{\lambda_1 (N_{c1})^2 + \lambda_2 (N_{c2})^2 + 10 - N_{c1} - N_{c2}}(\Gamma^{(l_i)} - 1)$$

or

$$[Es/Io]_{l_i} = \frac{(\lambda N_c + 10 - N_c)}{\lambda (N_c)^2 + 10 - N_c}(\Gamma^{(l_i)} - 1)$$

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 0111897.5	**Examiner:**	Paul Jenkins
Claims searched:	1-9	**Date of search:**	4 December 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H4L (LRPMA, LRPMW, LRRMW)

Int Cl (Ed.7): H04Q 7/38

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2318952 A (MOTOROLA)	-------
A	WO 00/25530 A2 (SIEMENS)	-------

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		